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AGRICULTURAL MEMORANDUM NO 373

Forecasting the date of apple blossom from records of air temperature

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1. Introduction. Pearce and Preston (1954) described a method of forecasting the date of blossom in apple trees (Bramley Seedling) at East Malling. This was based on regressions and partial regressions between the accumulated temperature above a base of 42°F after specified dates and the date of full blossom. Their formulae used in the forecasting of blossom date consisted of two parts, the relation between date of blossom and (i) accumulated temperature in the late winter-spring (negative correlation) and (ii) the accumulated temperature in June of the preceding year (positive correlation, ie hot weather delayed blossom in the next year). They show that with occasional exceptions forecasting on 16 March or even 1 March gives quite good agreement with actual blossom dates.

2. Present study. Some years ago a basically similar investigation was made for Beauty of Bath grown and recorded at Long Ashton. The methods used and results obtained are given in this paper.

3. Data and methods. The data available included the date of blossom annually from 1946 to 1954 and temperature data for the same period, expressed as day-degrees above (and below) 42°F for each Shaw Week. These were combined to give the winter-spring period summations annually over Shaw Weeks 13-25; for the summer period, accumulated temperature data were combined over Shaw Weeks 27-38.

The date of commencement of a selection of Shaw Weeks is given in Table 1 below.

Table 1. Commencing dates of selected Shaw Weeks

	Shaw Week Number						
	13	17	21*	25*	27*	31*	35*
Date	29 Jan	26 Feb	26 Mar	23 Apr	7 May	4 June	2 July

*Leap Year, dates one day earlier than given.

After a graphical check of the existence of an approximately linear relationship between the date of blossom and accumulated temperature above 42°F calculated from various dates, correlation coefficients were calculated to aid in the selection of summation periods.

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4. Winter-spring period.

Table 2. Correlation coefficients for summations in winter-spring, weeks 13-23

		First week number				
		13	15	17	19	21
Last week	14	-.85**				
number	16	-.86**	-.51			
	18	-.85**	-.60	-.31		
	20	-.82**	-.65	-.49	-.66	
	22	-.94**	-.89**	-.91**	-.92**	
	23	-.96**	-.92**	-.94**	-.93**	-.73*

**Significant at .01 level

*Significant at .05 level

The values in Table 2 suggest that the inclusion of the early weeks 13-14 is important. If these are not included there are no significant correlations until week 22 (commencing 2 April). Starting from week 13, however, correlations are significant throughout, even using only the first 2 weeks, 13-14.

As a basis for forecasting, regression coefficients were computed for the various periods, with the following results.

$$X = A - BY$$

where X is the computed date of blossom (day 1 = 23 April)

Y = no. of accumulated day-degrees for the appropriate period

A and B are constants, shown in Table 3 below.

Table 3. Constants in regression equations for various periods

	Period (Shaw Weeks)					
	13-14	13-16	13-18	13-20	13-22	13-23
A	20.2	23.9	26.0	29.0	34.2	37.3
B	.270	.175	.139	.097	.088	.085

5. Previous year, late spring-summer period. The visual examination for periods contained by Shaw Weeks 27-34 suggested correlations for periods commencing week 27. Computation showed that the correlation coefficient was close to the .05 significance value only for weeks 27-28 (May 8-21) when it was -.63.

6. Combined periods. Partial regressions were worked using the periods weeks 13-23

of the blossom year and weeks 27-28 of the previous year. These were in the form

$$X = K - B_1Y_1 - B_2Y_2$$

where X is the computed date of blossom (day 1 = 23 April).

Y_1 = no. of accumulated day-degrees for the appropriate period in the year of blossom

Y_2 = no. of accumulated day-degrees during weeks 27-28 of the previous year

K, B_1 and B_2 are constants, shown in Table 4 below.

Table 4. Constants in partial regression equations for various periods

Constants	Period (Shaw Weeks) in blossom year					
	13-14	13-16	13-18	13-20	13-22	13-23
K	22.68	16.17	32.61	37.88	35.01	37.99
B_1	.250	.234	.117	.080	.084	.083
B_2	.017	.064	.049	.066	.010	.007

7. Results and discussion. Using the constants given in 4 and 5 above and the appropriate accumulated number of day-degrees it is possible to make estimates of date of blossom based on temperatures of winter and spring of the same year, with or without a correction to allow for the effect of temperature during 2 weeks of the previous year. Tables 5 and 6 give these results.

Table 5. Estimates of date of blossom based on regression equations for periods within weeks 13-23 in the year of blossom, expressed as a deviation in days from actual date of blossom (- indicates forecast date earlier than actual date)

Period (Shaw Week)	Year								
	1946	1947	1948	1949	1950	1951	1952	1953	1954
13-14	-1	0	-2	7	2	-10	3	1	1
13-16	0	4	6	1	-4	-7	5	-1	-3
13-18	6	6	2	4	-4	-5	2	-1	-4
13-20	8	4	1	4	-5	-6	3	-1	-3
13-22	2	4	2	3	-5	-3	1	0	-3
13-23	1	3	2	-1	-3	-1	0	1	-4
Actual date	25A	12M	23A	29A	3M	19M	7M	7M	11M

Table 6. Estimates of date of blossom based on partial regression equations for periods within weeks 13-23 in the year of blossom and for weeks 27-28 of the previous year, expressed as a deviation from actual date of blossom (- indicates forecast date earlier than actual date)

Period (Shaw Week)	Year 1946	1947	1948	1949	1950	1951	1952	1953	1954
13-14	-1	1	0	6	2	-10	3	0	-1
13-16	1	4	5	1	-7	-6	3	0	3
13-18	3	7	2	2	-3	-6	1	2	-3
13-20	4	6	2	2	-3	-6	2	2	-2
13-22	2	4	2	2	-5	-3	2	0	-3
13-23	1	3	2	0	-3	-1	1	1	-4
Actual date	25A	12M	23A	29A	3M	19M	7M	7M	11M

It is clear that considered overall the inclusion of data for the previous year does not greatly affect the accuracy of forecasts. The arithmetic total of the entries in Table 5 is 166, compared with 151 in Table 6. Using the totals of the vertical column as an index, the use of weeks 27-28 improves the forecast in 5 years, has no effect in 3 years and leads to a less accurate forecast in one year, 1947. If, however, the larger errors are considered, the use of weeks 27-28 appears more worth while. Pearce and Preston suggest that errors of $\pm$ 3 or 4 days are of little practical importance and if our attention is confined to the errors exceeding 3 days, Table 5 contains 21 of these but only 14 occur in Table 6, and a reduction in the frequency of such errors is seen in 5 out of 9 years.

Table 7. Number of years out of 9 when forecast was correct within $\pm$ 3 days using (a) blossom year temperatures, and (b) current and previous years

	Period (Shaw Weeks) 13-14	13-16	13-18	13-20	13-22	13-23
a	7	4	3	4	7	8
b	7	5	7	6	7	8

If the improvement is considered in relation to the period of temperatures used, it is seen that the use of the previous year leads to no improvement with forecasts based on short or on long periods of temperature data in blossom year, but there is an improvement when periods of 4 to 8 weeks' data are used.

It is, of course, not certain that the effect of including these weeks is a real one. We must note that the correlation is a negative one, ie warmer weather in weeks 27-28 tends to advance the date of blossom in the following year. This is the opposite of the finding of Pearce and Preston, but they remarked that their finding of a positive correlation was rather unexpected.

Perhaps a more important point is the earliness of this period. Pearce and Preston found that their relationship applied to June, but weeks 27-28, used here for Beauty of Bath, cover the period May 8-21. Table 5 shows that in 3 out of the 9 years examined, blossom occurred within the period May 8-21.

In view of the closeness of weeks 27-28 to blossom time, it is possible that any apparent relation between blossom date and accumulated temperature during weeks 27-28 of the previous year is the result of a serial correlation between blossom dates (of consecutive years). To test this, this serial correlation was calculated. It was approximately -0.1 and not significant.

8. Conclusions. Reasonable agreement is found between actual dates of blossom and dates forecast using temperature data. The inclusion of dates from the previous year leads to some improvement, but this period coincides with blossom in a number of years and leads to the suspicion that it may be a chance effect (the relevant correlation coefficient approaches significance at the .05 level).

Table II of Pearce and Preston can be compared with Tables 5 and 6 above. Using the values given for 1946-53 in Pearce and Preston 56% of the forecasts are correct within $\pm$ 3 days. Using the same criterion the values from Table 5 show that 61% of the values are correct using only the temperature data for the current year and Table 6 shows that the addition of values for the previous year increases this to 74%. This does not imply an improvement on the results obtained by Pearce and Preston. Their values are based on regressions obtained from data for 18 years whereas ours are derived from regressions for the identical 8-year period for which estimates are made. This would tend to give closer fit for the estimates.

Generally, it may be concluded that the accuracy of the forecasts of date of blossom of Beauty of Bath at Long Ashton is similar to that obtained for Bramley's Seedling at East Malling. It would be of interest to obtain similar estimates for other varieties which have been recorded over many years, and particularly to investigate further the effect of particular periods in the previous season.

9. Acknowledgments. My thanks are due to the Director, Long Ashton Research Station for providing the blossom data and to J W Davies and A J Pearson for help in preparing this paper.

10. References.

Pearce S C and Preston A P 1954. Forecasting the time of blossoming in apple trees from temperature records. Rep. E. Malling Res. Sta. for 1953: 133-7.

Any comments or suggestions on this paper should be sent to the author.

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